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F-14 WING LUG COATING INVESTIGATION

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F-14 wing lugs have been painted with a special coating which prevents wear of the bearing and lug, and subsequent failure of the wing. The coating originally designated for this application contained talcs (extender pigments) which contain small concentrations of asbestos, causing discontinued manufacturing of the talcs and the coating. Since the performance of this coating is considered critical to flight, a replacement was needed to prevent grounding of the F-14 fleet. One requirement for the application of this coating was that it be processed by allowing the filler particles to settle, and subsequently decanting and applying the resin-rich upper layer of the mixed coating.

The original coating was reformulated by replacing the talcs with non-asbestos pigments with nearly equivalent chemical composition. This resulted in a pigment systems which does not settle as much as that in the original coating, and the applied film is far less wear resistant. Alternative high-performance coatings also displayed relatively poor abrasion resistance compared to the original coating. A mechanism for these results has been proposed. It is suspected that pigment-rich coatings with particles protruding through the surface allow the concentration of shear stresses

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INTRODUCTION

The F-14 wing lug is protected with a special coating which prevents wear of this bearing and subsequent failure of the wing. Figure 1 shows the location of the bearing within the F-14 wing. Figures 2 and 3 illustrate the bearing and the coated surface, respectively. The coating which was originally designated for this application is a DeSoto Chemical Company product (Berkeley, CA; formulation numbers: 825X374 and 910X486) which, at that time, was qualified under MIL-C-27725: COATING, CORROSION PREVENTIVE, FOR AIRCRAFT INTEGRAL FUEL TANKS. This coating is a two component polyurethane material which contains chromate pigments for corrosion inhibition, and various talc extender pigments for gloss reduction and viscosity control. This coating originally was developed for use in fuel tank areas and the recommended processing procedure was: thoroughly mix the two components, thin with the suitable solvent blend, and apply by spray. However, when prepared in this manner, the applied coating does not provide the desired wear characteristics for the bearing application. Therefore, a special processing technique was developed which requires that the coating be mixed and allowed to set untouched for 3 hours. As illustrated in Figure 4, this dwell time allows the pigments within the coating to partially settle, forming a resin-rich layer at the top. After this 3 hour period, the top 10% of the coating is separated and spray applied to the bearing surface. (Appendix A contains a detailed description of the preparation and application process.) It was found that preparing and applying the coating in this manner significantly increases its wear resistance properties as determined by Taber Abraser tests (ASTM D 4060) and 1/10th bearing tests performed by Grumman Aerospace Company. No historical literature or data are available on the coating selection process or the wear properties of the coating as determined by Grumman Aerospace.

Mistron T-076 (Cyprus Mines Corporation, Trenton, NJ) is one of the talcs contained within the above DeSoto coating. It contains primarily magnesium oxide (MgO) and silica (SiO_2). However, it also contains up to 2% asbestos and this caused its production to be discontinued. The other talc, CP44-31 Pfizer (New York, NY) also contains small quantities of asbestos and its production also has been discontinued. Consequently, the DeSoto coating formulation was modified by substituting Nicron 500 for Mistron T-076, and MP44-26 in place of CP44-31. Each of the new talcs are manufactured by Montana Talc Company, Three Forks, MT. Unfortunately, these modifications resulted in a coating which exhibits less pigment settling when mixed, and it is far less abrasion resistant when applied. Therefore, a new coating and/or process was required for wear protection of the F-14 wing lug and this was the objective of the effort discussed herein.

Several approaches to meeting the above objective were considered: investigate alternative processing procedures for the modified product, find a suitable commercial product, and/or develop a new product. The first two approaches were preferred since a new coating could not be developed and made commercially available before the original coating was out of stock at Grumman and NADEP. This could have resulted in grounding of F-14 aircraft.

EXPERIMENTAL APPROACH, MATERIALS, AND PROCEDURES

The first step in obtaining a suitable substitute coating and/or processing procedure was to determine the chemical and physical differences between the original and modified DeSoto coatings, and to identify those differences which cause variations in wear properties. Infrared spectroscopy was used to characterize the polyurethane binder of the original and modified coatings in both the pigmented and unpigmented conditions. In addition, chemical resistance of the applied cured coatings was evaluated by wiping with rags dampened with methyl ethyl ketone (MEK) and toluene, respectively. The latter test was used to ascertain differences in the cure condition of the applied films.

The talcs were chemically characterized using atomic emission spectroscopy. Scanning electron microscopy was used to study their size, shape, morphology, and topography. Oil absorption and density of talc samples were determined according to ASTM D 281 and D 153, respectively.

While characterization of the original and modified coatings was underway, a concurrent investigation of alternative coatings was conducted. This investigation was intended to determine if a commercially available product existed which would match the wear characteristics of the original DeSoto coating. In order to perform this segment of the project, several high performance coatings were selected. This selection was determined on the basis of previous history of high performance coatings and generic high performance binders. Table 1 lists the coatings evaluated and their respective specifications. These coatings were prepared and applied as suggested by the manufacturer and not by the settling method used with the original and modified F-14 wing bearing coatings. They were applied to a dry film thickness of 1.8 $\pm$ 0.2 mils using conventional air spray. The curing conditions after application consisted of the following: 3 hours at 70° F, 30 minutes at 205° F, 40 minutes at 335° F, and 4 hours at 310° F.

Table 2 lists the tests used to characterize the physical properties of the coatings under evaluation. The Taber abraser was used to evaluate wear characteristics because it had been reported verbally that this test was originally used by Grumman to select the most wear resistant coating for the F-14 wing bearing application. Adhesion, impact flexibility, water and chemical resistance tests were performed to compare physical and chemical characteristics of the cured coatings, and to ensure that the selected coating could withstand typical aircraft operational and environmental conditions.

Alternative processing procedures were developed and investigated after chemically and physically characterizing the original and modified DeSoto coatings and coating components (binder and pigments), and evaluating several commercially available coatings. Details of this phase will be presented in the RESULTS AND DISCUSSION section below.

RESULTS AND DISCUSSION

Infrared spectroscopy analysis (Figure 5) of the original and modified DeSoto coatings indicated no significant difference in the polyurethane binder. In addition, the solvent wipe tests using MEK and toluene resulted in

no dissolution or swelling of either coating, thus indicating that they both were resistant to these solvents, and providing additional evidence that the binders were similar. This finding was not surprising considering that DeSoto representatives claimed that the same isocyanate and polyester raw materials were used in both products. However, there is a slight potential for the two talcs to cause different catalysis mechanisms for the isocyanate-polyester reaction (which results in the urethane). In turn, these differences may have caused variations in the resulting polyurethane binder. The infrared spectroscopy and chemical resistance results confirmed that this was not the case.

In-house atomic emission spectroscopy (AES) was performed to determine the chemical composition of the various talcs in question. These results are listed in Table 3. In general, they agree with the manufacturer's composition data. However, there were some minor variations between the original and replacement talcs which may have led to differences in catalysis mechanisms mentioned above. After reviewing all of the chemical and physical results, it was concluded that these chemical differences did not have an effect on wear properties of the coating.

Scanning electron microscopy (SEM) at a magnification of 2000X (Figure 6) did indicate slight differences in size and shape of the talcs. The newer talc appeared "fluffier" which was confirmed by comparing the surface area of the two talcs. The substitute talc (Nicron 500) has a surface area of 12 m^2/g and the original talc (Mistron T-076) has a surface area of 9 m^2/g. Since they have the same density, this would cause the newer talc to be more susceptible to interactions with the polymer and solvent, thus making it more "buoyant" and able to remain suspended in the paint mixture. This accounts for the observation that the pigment in the modified coating did not settle as quickly or as much as that in the original coating.

While characterization of the coatings and coating components was underway, a simultaneous effort was undertaken to evaluate the wear resistance of alternative coatings. Since epoxy and polyurethanes are the most common high performance industrial coatings, several commercially available coatings containing one of these binders, along with the original and modified DeSoto bearing coatings, were evaluated using the Taber abraser. These results are presented in Table 4 and it is clear that the original wing bearing coating has superior abrasion resistance properties in the Taber abraser evaluation. The other coatings did not exhibit good wear properties relative to the original DeSoto coatings and therefore they were discontinued from the investigation.

It was evident from the abrasion results presented in Table 4 and the characterization data and observations discussed above, that the original DeSoto coating prepared with the pigment settling procedure had special characteristics which enhanced its wear resistant properties. One obvious difference is the resin-rich nature of the applied coating, which is caused by the settling action of the pigments. The other coatings are well known for their adhesion, toughness and durability but they have much higher pigment loading levels in the applied state. This is evident by their low gloss which is caused by pigment particles protruding from the surface of the coating. These observations led to a proposed mechanism for the abrasion process (Figure 7). The higher filler loading levels result in a rougher surface

topography. High points on this surface concentrate shear stresses during the abrasion action. These stresses pull filler particles (and possibly binder adhering to these particles) from the coating, creating a crevice which further increases the roughness of the coating surface. In addition, filler particles are 2 to 5 times more dense than the polymer matrix and therefore removal of these particles has a greater effect as observed in the Taber abraser (weight loss) results. In contrast, the original DeSoto coating, when applied as specified in Appendix A, has less filler due to the settling action. This results in a smoother applied coating surface which is not as susceptible to the abrasive action. This mechanism has not been confirmed but it is consistent with all of the results and observations obtained during this investigation.

Based on the above results and the proposed mechanism, it was thought that a coating surface similar to that obtained with the original coating, using the pigment settling process, would result in an acceptable abrasion resistant film. To accomplish this, it was necessary to produce a coating which was resin-rich with the polyurethane binder of the original coating. Two approaches to accomplish this were developed and studied, forced pigment sedimentation and cure retardation. The forced sedimentation was accomplished by centrifuging the mixed coating in a floor model industrial centrifuge, at 1000 RPM for 1 hour. This caused the more dense filler particles to partially separate from the binder. Following centrifugation, the top 50% of the coating was decanted and spray applied. Appendix B provides detailed procedures for this method.

The second approach was to retard the cure rate of the polyurethane in order to provide more time for the pigments to settle. This was accomplished by refrigerating mixed samples of the coating at 40° F for 48 hours. At this time, the top 10% of the coating was decanted and spray applied. Appendix B also provides detailed procedures for this method.

At this point in the investigation, the modified version of the bearing coating was prepared and applied using the centrifugation and refrigeration procedures. In addition, an updated version of the fuel tank coating (MIL-C-27725, Type II, Class B), which contains the same binder as the original and modified coatings, was obtained from DeSoto and tested using the above procedures. A sample of the clear, unpigmented resin system was also obtained and tested. The results of this segment of the investigation are presented in Table 5. These results clearly indicate that the refrigeration and centrifugation methods with the modified and current (fuel tank) coatings yield films with superior abrasion resistance. The unpigmented coating also exhibits good abrasion resistance. These results are completely consistent with the model and mechanism proposed earlier (Figure 6).

Adhesion (wet tape and scrape) and impact elongation tests illustrate that the properties of these applied coatings are similar to the original coating. In general, these results strongly suggest that the modified and current coatings applied with the new procedures will perform similarly to the original coating on F-14 wing bearings in-service. One benefit of the centrifugation method which uses 50% of the mixed coating versus 10% for the original and refrigeration procedures is more efficient use of the coating and less hazardous waste.

In order to determine the effects of hydraulic and lubricating fluids, specimens with the applied coatings were immersed in MIL-H-83282 and MIL-L-23699 at 150° F for seven days. The hardness of these films before and after exposure were equivalent, indicating no effect.

APPLICATION AT NADEP NORFOLK

On 13 February 1992, personnel in the materials engineering section and paint shop at NADEP Norfolk prepared and applied the DeSoto fuel tank coating (MIL-C-87725B, Type II, Class B) using the centrifugation technique described in Appendix B. Four samples of the coating were mixed and poured into 100 ml round-bottom centrifuge tubes. These tubes were placed in a floor model centrifuge and rotated at 1000 RPM for 30 minutes. This yielded a mixture similar to that obtained at NAWCACDIVWAR, with a clear distinction of pigment settling in the lower half of the tube. The top 50% of the samples were separated into plastic containers and taken to the shop for application.

Prior to paint application, the wind lug surfaces appeared smooth and clean, with an extremely uniform chromate conversion coating. The coating was applied using conventional air spray at a relatively low pressure (30 PSI). Upon spraying the upper lug surface, several fish-eyes appeared, indicating contamination in the paint or on the surface. A second coat reduced this problem slightly by allowing the second coating to wet and flow over the first coat. The bottom lug was painted by first applying a very light "mist" coat and allowing this to set for 5 to 10 minutes before applying the second and third coats. This latter procedure reduced the number and size of fish-eyes but 2 or 3 still formed. Nonetheless, the applied coatings appeared to be suitable to pass quality assurance inspection.

It was recommended that the painting shop obtain a suitable centrifuge and glassware specifically designated for this procedure. It is expected that these precautions will minimized contamination in future applications.

SUMMARY AND CONCLUSIONS

The two-component polyurethane coating originally applied to F-14 wing lugs for wear protection was processed by allowing filler particles to settle and subsequently decanting and applying the resin-rich upper layer of the mixed coating. This material contained talcs (extender pigments) which have small concentrations of asbestos, causing discontinuation of the talcs and the coating. The coating was reformulated using non-asbestos talcs with nearly equivalent chemical composition; however, this resulted in a pigment system which does not settle as much as that in the original coating and the applied film is far less wear resistant. It is suspected that the reduced pigment settling is caused by lower pigment densities and more talc-polymer interactions, allowing these particles to remain suspended for an extended period of time.

Alternative high-performance epoxy and polyurethane coatings were evaluated and they do not exhibit the superior wear resistance characteristics of the original coating. It appears that one cause for this is concentrated shear stresses on particles protruding through the applied coating surface

during abrasion processes. The original coating is processed by allowing the majority of pigment particles to settle out, thus causing a resin-rich coating which has less surface irregularities and is more wear resistant.

In order to re-create the pigment settling effect, two processing procedures for the modified coating were developed. The first is a centrifugation technique which forces the filler particles in the mixed coating to settle under centrifugal force. The second technique is to retard the polyurethane cure kinetics, allowing additional time for pigment settling to occur. This cure retardation is accomplished by lowering the temperature of the mixed coating. The specific processing procedures are detailed in Appendix B. After pigment settling, the resin-rich layer of the modified coating is decanted and applied. These coatings exhibited wear properties superior to all of the coatings tested, including the original material. When processed according to these procedures, the modified coating also exhibits acceptable adhesion, flexibility, fluid resistance, and hardness properties for use on Navy aircraft applications.

Table 1: High Performance Coatings Evaluated for Wear Resistance.

COATING	BINDER	SPECIFICATION	MANUFACTURER
Original wing bearing coating	Polyurethane		DeSoto
Modified wing bearing coating	Polyurethane		DeSoto
Self-priming topcoat (Camouflage)	Polyurethane	TT-P-2756	Dexter
Self-priming topcoat (High gloss)	Polyurethane	TT-P-2756	Dexter
Solvent-borne primer	Epoxy	MIL-P-23377	Deft
Super Koropon	Epoxy	MMS-415	DeSoto
Standard paint system	Epoxy Primer/ Polyurethane Topcoat	MIL-P-23377 MIL-C-85285	Deft Deft
Touch-up topcoat	Epoxy	MIL-C-22750	Deft
Flexible primer	Polyurethane	TT-P-2760	DeSoto

Table 2: Test Procedures Used to Evaluate Coating Performance.

Property	Test Method
Abrasion	Taber abraser (ASTM D 4060, wheel CS17)
Adhesion	Scrape adhesion (ASTM D 2197) Wet tape test (ASTM D 3359, Method A) after 24 hours immersion in distilled water at 75° F
Flexibility	Impact flexibility (Federal Test Method Standard 141C, method 6226)
Fluid Resistance	Hydraulic fluid (24 hr immersion in MIL-H-83282 at 150° F) Engine oil (24 hr immersion in MIL-L-23699 at 250° F)
Hardness	Pencil hardness (ASTM D 3363) after immersion in hydraulic fluid and engine oil, respectively

Table 3: Talc compositions as determined from atomic emission spectroscopy.

	Original Talc	Replacement Talcs	
Composition*	Mistron T076	Nicron 500	MP44-26
SiO_2	56	62	60
MgO	25	30	26
CaO	6.0	0.2	0.2
Al_2O_3	0.4	Trace	0.5
Fe_2O_3	0.4	1.1	0.8

* The remaining compound in the talc composition are primarily H_2O and CO_2 Information on and samples of CP-44-31 were unavailable. Production of this material was stopped in the late 1980's.

Table 4: Taber abraser results on high performance coatings.

Coating	Weight loss per 1000 revolutions
Original coating	32 milligrams
Modified coating	96
Self-Priming topcoat (camouflage)	89
Self-priming topcoat (high gloss)	44
Epoxy primer	102
Super Koropon	188
Standard paint system	45
Touch-up topcoat	76
Flexible primer	169

Note: The original and modified wing lug coatings were prepared and applied as described in Appendix A. The remaining coatings were prepared and applied per manufacturer and/or specification instructions. The Taber abraser weight loss values are an average of at least 4 replicates. Standard deviations were approximately 5% of the average.

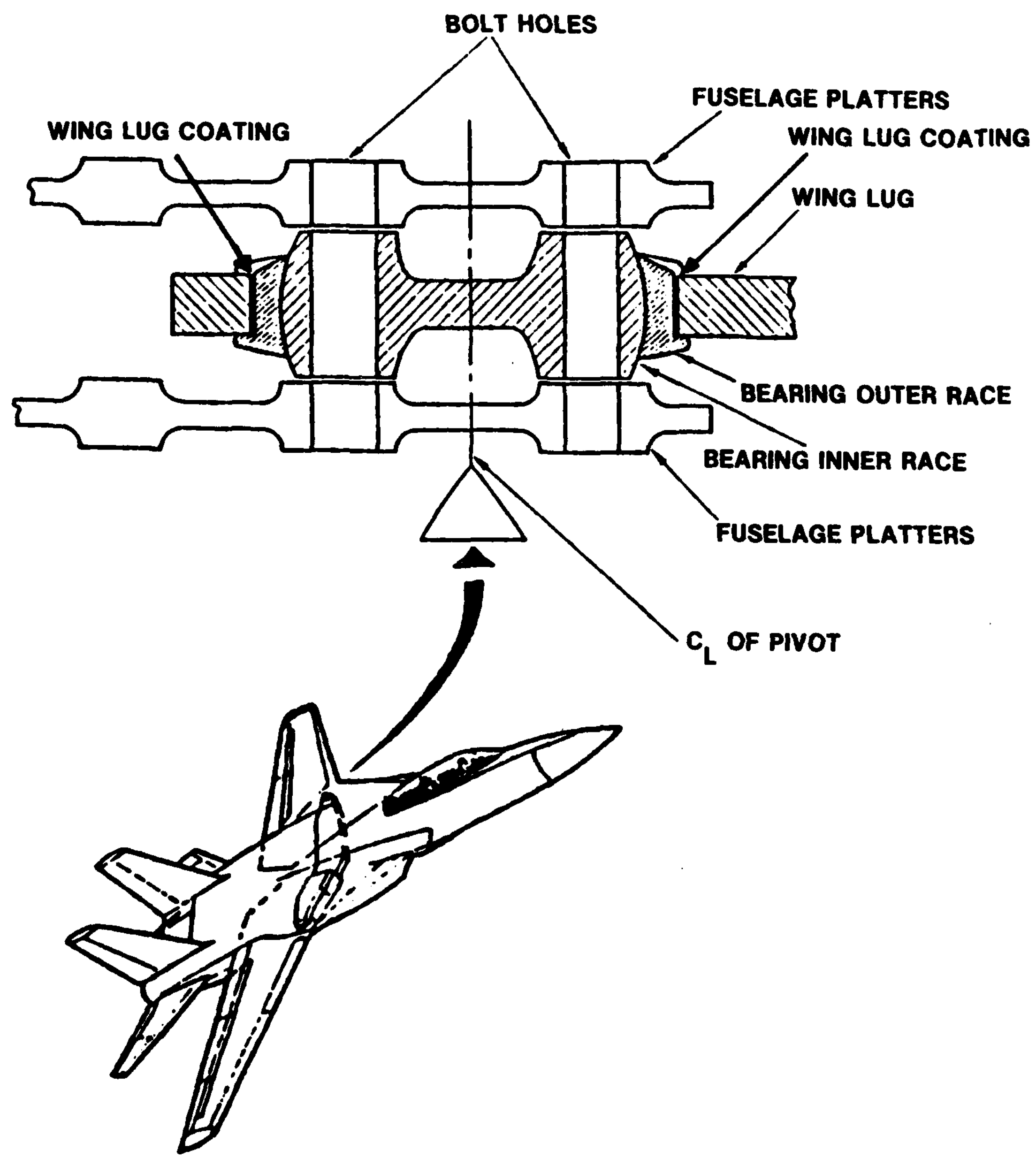

Figure 1: Location of Bearing within F-14 Wing.

Figure 2: F-14 Wing Lug Seal and Bearing

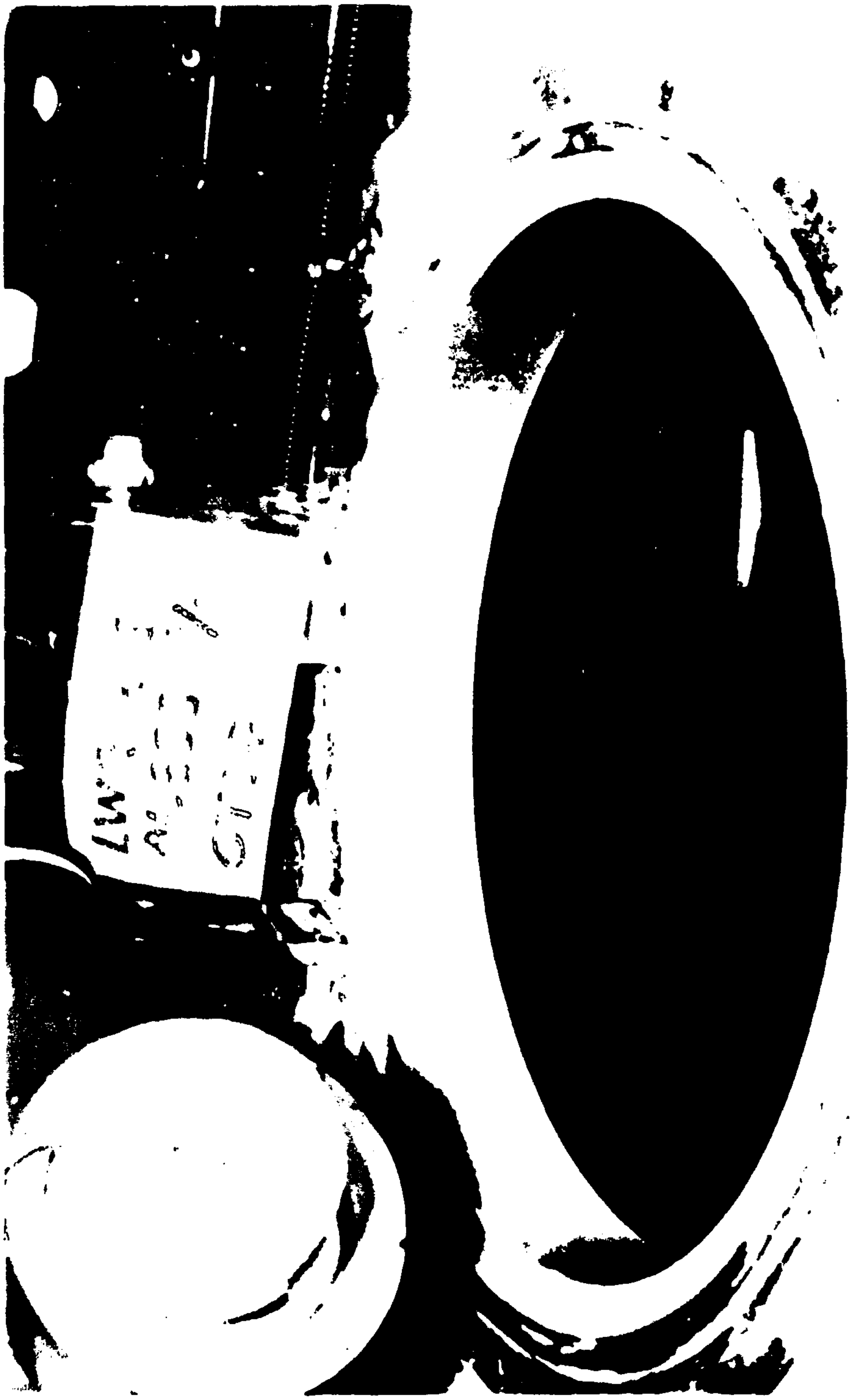

Figure 3: Coated Lower Lug Surface.

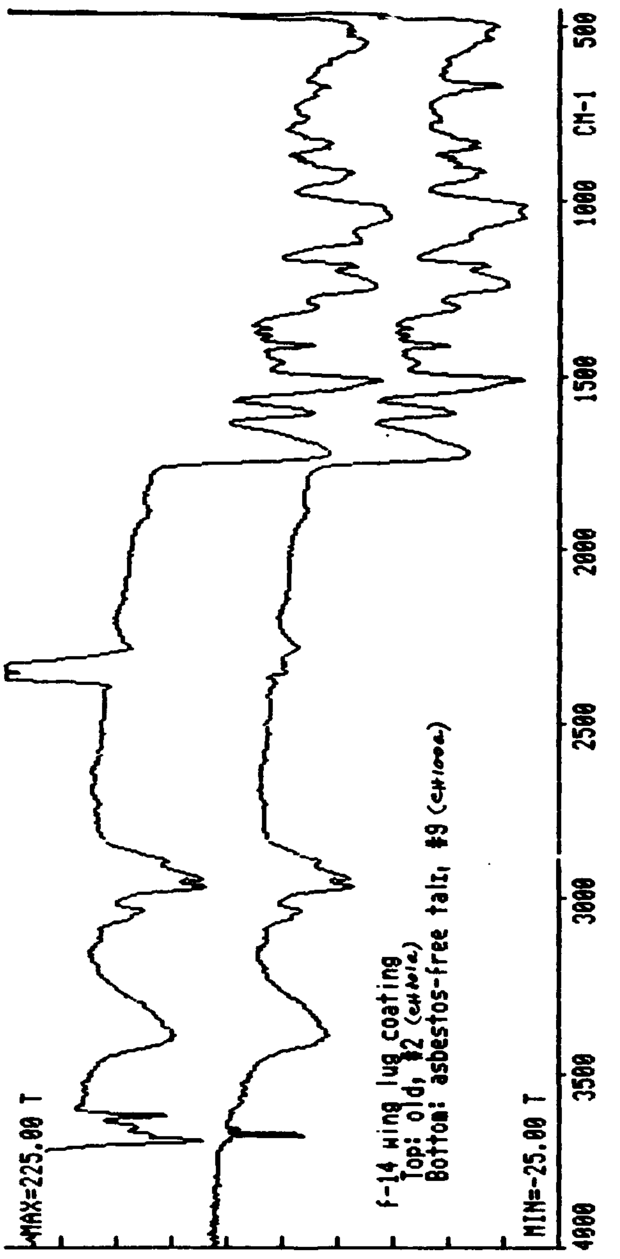

Figure 4: Infrared Spectrum of Original and Modified Coatings.

MODIFIED ORIGINAL

24 Hr Dwell

Figure 5: Illustration of Pigment Settling in Orignginal and Modified Coatings.

MICRON 500

T076

Figure 6: Scanning Electron Micrographs (2000X) of Talcs.

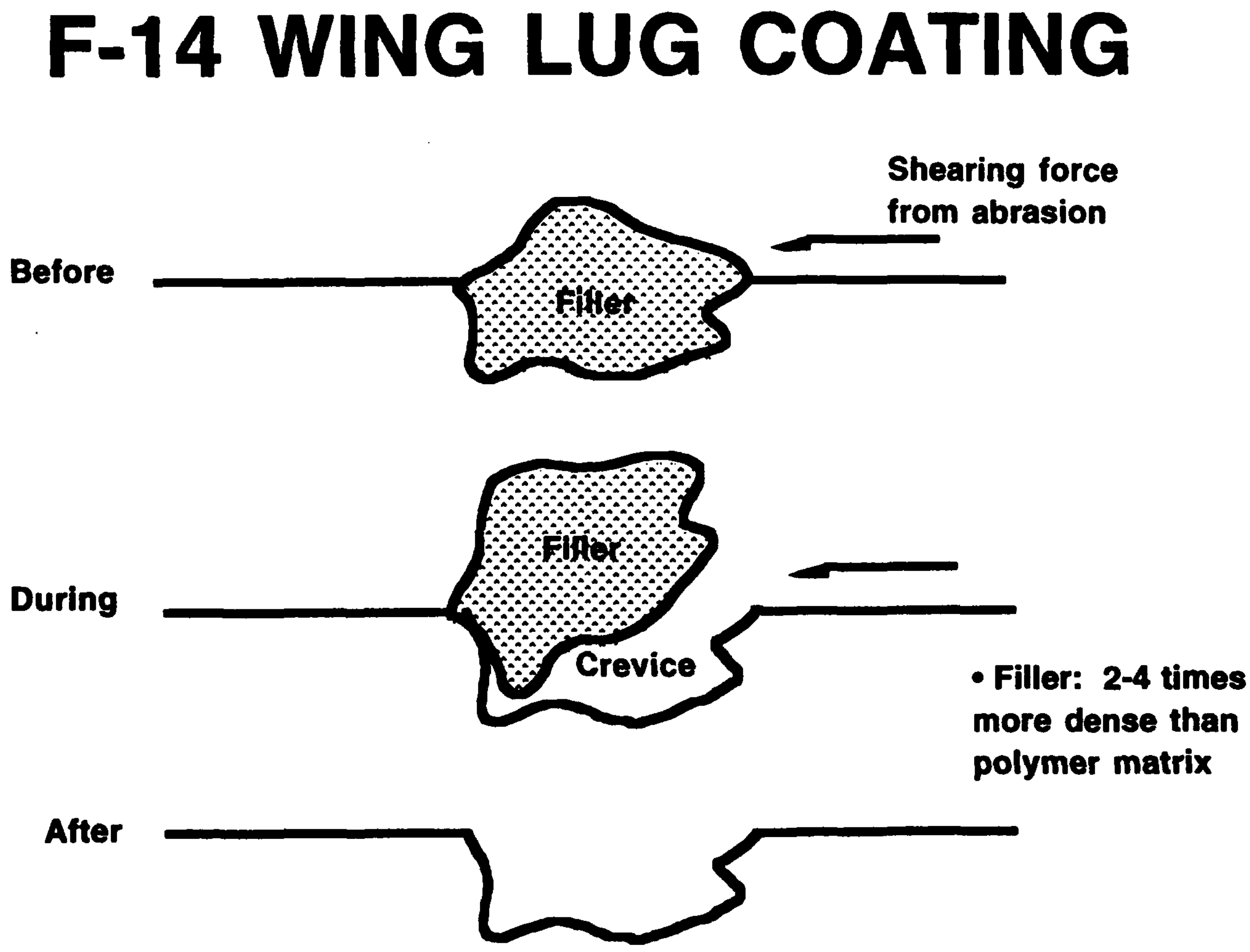

Figure 7: Proposed Mechanism of Coating Abrasion Process.

APPENDIX A

ORIGINAL PROCESSING PROCEDURES FOR F-14 WING LUG COATING APPLICATION

Material: F-14 Wing Lug Coating manufactured by DeSoto Inc., Berkley, CA. Product designations - base 825-375, curing solution 910-486, and thinner 020-336. Mix ratio of components - 4 parts by volume of base, 1 part of curing solution, and 4 parts of thinner.

Procedure (from NADEP Norfolk F-14 Local Engineering Specficiation, NO(35) 6921, Paragraph 7):

1. Place a 12 by 12 inch clean plastic Ziploc bag in a 1 gallon can.

2. Thoroughly shake the base material on a paint mixer to ensure a uniform resin dispersion. Open the base material in a controlled atmosphere area and pour the base into the clean plastic bag in the gallon can.

3. Open the accelerator (curing agent) in a controlled atmosphere area. If the accelerator is cloudy, gelled, or contains crystalline material, discard the accelerator, base, and thinner. Obtain a fresh sample of material.

4. Add the accelerator to the base with stirring. Check the bottom of the accelerator can for evidence of gelled or crystalline material. In gelled or crystalline material is present, discard the base, accelerator, and thinner. Obtain a fresh sample of material.

5. Add 80% of the thinner to the mixed accelerator and base. Mix thoroughly. Add half of the remaining thinner to the original containers of the base and accelerator. Stir the thinner in the original containers and add to the gallon container. Mix thoroughly.

6. Allow the mixed material to stand for a 3 hour dwell time with no agitation. The mixed material shall be covered during the 3 hour dwell time. The material must be used within 0.5 hour after the expiration of the dwell time. The time shall be recorded at the beginning of the dwell time.

7. After the 3 hour dwell time, ladle the top 10% of the coating mixture, without mixing, through a 240 mesh silk cloth. The coating material may not be disturbed, agitated, or stirred during the 3 hour dwell time or afterward. Discard the remaining 90% of the material. It is not serviceable.

8. Pour the strained material into the cup of an air gun, such as DeVilbiss Type EGA, Series 502 or equivalent. Spray a sufficient number of coats to produce a dry film thickness of 0.8 to 1.5 mils. At no time may the thickness exceed 2.0 mils The coating shall be sprayed on heavy almost to the point of running. A light "dry" spray coat will not give satisfactory adhesion. The final sprayed coating will be very slight marbled or orange peel effect. The final sprayed coating will be a high gloss translucent light green.

9. Coated parts shall dry in a controlled atmosphere for a minimum of 1.5 hours. After 1.5 hours, the wing may be removed from the controlled atmosphere. If removed, the lug shall be protected and the coating shall be allowed to cure for a additional 1.5 hours minimum for a 3 hour minimum air

cure.

10. Subject the coating to the following heat cycle for final cure:

30 minutes at 205° F
40 minutes at 335° F
4 hours at 310° F

APPENEDIX B

CENTRIFUGATION PROCESSING PROCEDURES FOR F-14 WING LUG COATING APPLICATION

Material: Integral Fuel Tank Coating, MIL-C-27725B, Type II, Class B manufactured by DeSoto Inc., Berkley, CA. Product designations - base component 832-707, curing solution 910-702, and thinner 020-707. Mix ratio of components - 4 parts by volume of base, 1 part of curing solution, and 4 parts thinner.

Procedure:

1. Stir or shake base material until uniform.

2. Thoroughly mix base, curing solution and solvent in a 4:1:4 ratio.

3. Let material stand covered at ambient conditions for 1 hour.

4. Re-stir material and pour into centrifuge tubes.

5. Centrifuge for 30 to 60 minutes at 1000 rotations per minute (RPM). At this time these should be a clear indication of pigment settling at the bottom 50% of the mixture.

6. Decant or pipette off the top 50% (resin-rich layer) and filter this portion through a 240 mesh silk cloth.

7. Properly discard remaining 50% (pigment-rich layer) of material.

8. Spray apply to produce a dry coating (0.8 to 1.5 mils). This is best accomplished by spraying thin coats.

9. Allow wing lug to dry at ambient conditions for a minimum of 3 hours prior to heat curing.

10. Subject applied coating to heat cycle as with original coating:

    3 hours at 70° F
    30 minutes at 205° F
    40 minutes at 335° F and
    4 hours at 310° F

REFRIGERATION PROCESSING PROCEDURES FOR F-14 WING LUG COATING APPLICATION

Material: Integral Fuel tank Coating, MIL-C-27725B, Type II, Class B manufactured by DeSoto, Inc., Berkley, CA. Product designations - base component 832-707, curing solution 910-702, and thinner 020-707. Mix ratio of components - 4 parts by volume of base, 1 part of curing solution, and 4 parts thinner.

Procedure:

1. Mix or shake base material until uniform.

2. Mix base, curing solution, and solvent in a 4:1:4 ratio.

3. Place covered material in refrigerator at 40° F for 48 hours.

4. Remove material and let stand at room temperature for 3 hours.

5. Decant or pipette off top 10% and filter through a 240 mesh silk cloth.

6. Discard remaining 90% of material.

7. Spray apply to produce dry coating (0.8 to 1.5 mils). This is best accomplished by spraying several thin coats.

8. Subject coating through heat curing cycle described in above procedure.

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